

What is claimed is:

1. A method, comprising:

depositing Mg onto a surface of an underlayer to form a Mg layer thereon, wherein the

5 surface is selected to be substantially free of oxide; and

directing additional Mg, in the presence of oxygen, towards the Mg layer to form a MgO

tunnel barrier in contact with the underlayer, the oxygen reacting with the additional Mg

and the Mg layer.

2. The method of Claim 1, wherein the thickness of the Mg layer is selected to be

10 large enough to prevent oxidation of the underlayer but small enough that, upon reaction

of the oxygen with the Mg layer, substantially all the Mg in the Mg layer is converted

into MgO.

3. The method of Claim 1, further comprising annealing the MgO tunnel barrier to

improve its performance.

15 4. The method of Claim 1, wherein the Mg layer is deposited in the absence of

substantial amounts of reactive oxygen, the Mg layer being oxidized as the MgO tunnel

barrier is formed.

5. The method of Claim 1, further comprising providing a source of MgO that acts

as a source of both oxygen and the additional Mg.

20 6. The method of Claim 1, wherein the oxygen includes ionized oxygen.

7. The method of Claim 1, wherein the oxygen includes atomic oxygen.

8. The method of Claim 1, wherein oxygen is provided by a rare gas-oxygen plasma.

9. The method of Claim 8, wherein the rare gas includes argon.

10. The method of Claim 1, wherein the MgO tunnel barrier has a thickness of between 3 and 50 angstroms.
11. The method of Claim 1, wherein the additional Mg is provided by at least one of the following techniques: reactive sputtering, ion-beam sputtering, evaporation, pulsed laser deposition, and molecular beam epitaxy.
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12. The method of Claim 1, wherein the Mg layer has a thickness of between 3 and 20 angstroms.
13. The method of Claim 1, wherein the Mg layer has a thickness of between 4 and 8 angstroms.
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14. The method of Claim 1, wherein the underlayer includes a semiconductor.
15. The method of Claim 14, wherein the semiconductor is in direct contact with the MgO tunnel barrier.
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16. The method of Claim 14, wherein the underlayer includes GaAs.
17. The method of Claim 1, wherein the underlayer includes a ferrimagnetic material.
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18. The method of Claim 17, wherein the ferrimagnetic material is in direct contact with the MgO tunnel barrier.
19. The method of Claim 1, further comprising forming an overlayer on the MgO tunnel barrier, wherein the overlayer includes a ferrimagnetic material.
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21. The method of Claim 1, wherein the underlayer includes a ferromagnetic material.
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22. The method of Claim 20, wherein the ferromagnetic material is in direct contact with the MgO tunnel barrier.
22. The method of Claim 20, wherein the ferromagnetic material includes Fe.

23. The method of Claim 22, wherein the ferromagnetic material is bcc and substantially (100) oriented.

24. The method of Claim 20, wherein the ferromagnetic material includes an alloy of Fe and Co and the Fe content of the alloy is between 1 and 99 atomic %.

5 25. The method of Claim 24, wherein the alloy is bcc and substantially (100) oriented.

26. The method of Claim 20, further comprising forming an overlayer on the MgO tunnel barrier to form a magnetic tunnel junction, wherein the overlayer includes a ferromagnetic material.

10 27. The method of Claim 26, wherein the oxygen content is selected to increase the magnetoresistance of the magnetic tunnel junction.

28. The method of Claim 26, further comprising annealing the tunnel junction to increase its tunnel magnetoresistance.

29. The method of Claim 28, wherein the tunnel junction is annealed at a temperature selected to yield a tunnel magnetoresistance of greater than 100% at room temperature.

15 30. The method of Claim 28, wherein the tunnel junction is annealed at a temperature selected to yield a tunnel magnetoresistance of greater than 160% at room temperature.

31. The method of Claim 26, wherein the overlayer and the underlayer include ferromagnetic materials selected from the group consisting of i) Fe, ii) an alloy of Co and

20 Fe, iii) an alloy of Ni and Fe, and iv) an alloy of Ni and Fe and Co.

32. The method of Claim 26, wherein the ferromagnetic materials are an alloy of Co and Fe, and the Fe content of the alloy is 10-20 atomic %.

33. The method of Claim 26, wherein the ferromagnetic material of the underlayer is bcc and is substantially (100) oriented.

34. The method of Claim 26, wherein the ferromagnetic material of the underlayer, the ferromagnetic material of the overlayer, and the MgO tunnel barrier are substantially (100) oriented.

35. The method of Claim 26, wherein at least one of the underlayer and the overlayer includes antiferromagnetic material that is exchange biased with the ferromagnetic material of said at least one layer, the antiferromagnetic material including at least one alloy selected from the group consisting of Ir-Mn and Pt-Mn, in which the alloy is substantially (100) oriented and is either fcc or slightly distorted fcc.

36. The method of Claim 26, wherein the underlayer includes antiferromagnetic material over at least one layer selected from the group consisting of Ta and TaN.

37. The method of Claim 26, wherein the MgO tunnel barrier is in direct contact with both the ferromagnetic material of the underlayer and the ferromagnetic material of the overlayer.

38. The method of Claim 1, comprising forming an overlayer on the MgO tunnel barrier, wherein one of the overlayer and the underlayer includes a non-ferromagnetic, non-ferrimagnetic metal layer, and the other of the overlayer and the underlayer includes a ferrimagnetic layer.

20 39. The method of Claim 1, comprising forming an overlayer on the MgO tunnel barrier, wherein one of the overlayer and the underlayer includes a non-ferromagnetic, non-ferrimagnetic metal layer, and the other of the overlayer and the underlayer includes a ferromagnetic layer.

40. The method of Claim 39, comprising constructing a magnetic tunneling transistor that includes the non-ferromagnetic, non-ferrimagnetic metal layer, the MgO tunnel barrier, and the ferromagnetic layer.

41. The method of Claim 39, wherein the non-ferromagnetic, non-ferrimagnetic metal layer includes a metal selected from the group consisting of Cu, W, Al, AlN, Nb, NbN, WTi, Ti, TiN, Ta, and TaN.

42. The method of Claim 39, wherein the ferromagnetic layer includes a ferromagnetic material selected from the group consisting of i) Fe, ii) an alloy of Co and Fe, iii) an alloy of Ni and Fe, and iv) an alloy of Ni and Fe and Co.

10 43. The method of Claim 39, wherein the ferromagnetic material and the MgO tunnel barrier are substantially (100) oriented, and the ferromagnetic material is bcc.

44. The method of Claim 1, comprising forming an overlayer on the MgO tunnel barrier, wherein the overlayer and the underlayer comprise respective non-ferromagnetic, non-ferrimagnetic metals.

15 45. The method of Claim 44, wherein the metals are selected from the group consisting of Cu, Al, AlN, W, Nb, NbN, Pt, Pd, Ir, RuO₂, Ru, and IrO₂.

46. A method, comprising:
constructing a magnetic tunnel junction that includes a MgO tunnel barrier, wherein the MgO tunnel barrier is formed by depositing Mg, in the presence of oxygen, onto a Mg layer substantially free of oxide.

20 47. The method of Claim 46, wherein oxygen is provided by a rare gas-oxygen plasma.

48. The method of Claim 46, wherein the Mg layer has a thickness of between 3 and 20 angstroms.

49. The method of Claim 46, further comprising annealing the magnetic tunnel junction to increase its magnetoresistance.

5 50. The method of Claim 49, wherein the tunnel junction is annealed at a temperature selected to yield a tunnel magnetoresistance of greater than 100% at room temperature.

51. The method of Claim 49, wherein the tunnel junction is annealed at a temperature selected to yield a tunnel magnetoresistance of greater than 160% at room temperature.

52. A method, comprising:

10 forming a layer of Mg;

providing an oxidizing atmosphere;

depositing Mg, in the presence of the oxidizing atmosphere, onto the Mg layer to form a MgO tunnel barrier.

53. The method of Claim 52, wherein the Mg layer is formed on a ferrimagnetic 15 layer.

54. The method of Claim 52, wherein the Mg layer is formed on a ferromagnetic layer, the method further comprising forming a ferromagnetic layer on the MgO tunnel barrier to construct a magnetic tunnel junction.

55. The method of Claim 52, further comprising annealing the MgO tunnel barrier to 20 improve its performance.

56. A method, comprising:

providing an underlayer having a surface that is substantially free of oxide;

forming a metal layer on the surface to both protect the underlayer from oxidation and to wet the underlayer; and

directing Mg and oxygen onto the metal layer to form a MgO tunnel barrier that is contact with the underlayer.

5 57. The method of Claim 56, wherein the underlayer includes at least one material selected from the group consisting of ferrimagnetic materials and ferromagnetic materials.

58. The method of Claim 56, wherein the metal layer includes Mg.

59. The method of Claim 56, further comprising annealing the MgO tunnel barrier to 10 improve its performance.

60. A method, comprising:

forming a Mg layer of a preselected thickness on a surface of an underlayer to protect the underlayer from oxidation; and

15 directing oxygen and additional Mg towards the Mg layer so that the oxygen reacts with the Mg layer and the additional Mg to form a MgO tunnel barrier on the underlayer, wherein the thickness of the Mg layer is selected to be small enough that substantially all the Mg of the Mg layer reacts with oxygen to form MgO.

61. The method of Claim 60, wherein the surface is selected to be substantially free of oxide.

20 62. The method of Claim 60, further comprising forming an overlayer on the MgO tunnel barrier, wherein the overlayer and the underlayer each include ferromagnetic material, thereby forming a magnetic tunnel junction.

63. The method of Claim 60, further comprising forming an overlayer on the MgO tunnel barrier, wherein the overlayer and the underlayer each include at least one material selected from the group consisting of ferromagnetic materials and ferrimagnetic materials, thereby forming a magnetic tunnel junction.

5 64. The method of Claim 63, further comprising annealing the magnetic tunnel junction to increase its tunnel magnetoresistance.

65. A structure, comprising:

an underlayer having a surface that is substantially free of oxide formed from the underlayer;

10 a MgO tunnel barrier in contact with the surface of the underlayer; and
an overlayer, the MgO tunnel barrier being in contact with a surface of the overlayer, the MgO tunnel barrier being sandwiched between the underlayer and the overlayer.

66. The structure of Claim 65, wherein the surface of the overlayer is substantially free of oxide formed from the overlayer.

15 67. The structure of Claim 65, wherein at least one of the overlayer and the underlayer includes a spacer layer that is in contact with the MgO tunnel barrier, wherein the spacer layer does not substantially interfere with the tunneling properties of the MgO tunnel barrier.

68. The structure of Claim 65, wherein the MgO tunnel barrier has a thickness of
20 between 3 and 50 angstroms.

69. The structure of Claim 65, wherein at least one of the underlayer and the overlayer includes a ferrimagnetic material.

70. The structure of Claim 65, wherein the overlayer and the underlayer include respective ferromagnetic materials that together with the MgO tunnel junction form a magnetic tunnel junction, and wherein:

- i) the amount of any oxide separating the MgO tunnel barrier from the ferromagnetic materials is sufficiently low, and
- 5 ii) the MgO tunnel barrier, the underlayer, and the overlayer are sufficiently free of defects,

that the tunnel magnetoresistance of the magnetic tunnel junction is greater than 70% at room temperature.

10 71. The structure of Claim 70, wherein

- i) the amount of any oxide separating the MgO tunnel barrier from the ferromagnetic materials is sufficiently low, and
- ii) the MgO tunnel barrier, the underlayer, and the overlayer are sufficiently free of defects,

15 that the tunnel magnetoresistance of the magnetic tunnel junction is greater than 100% at room temperature.

72. The structure of Claim 70, wherein

- i) the amount of any oxide separating the MgO tunnel barrier from the ferromagnetic materials is sufficiently low, and
- 20 ii) the MgO tunnel barrier, the underlayer, and the overlayer are sufficiently free of defects,

that the tunnel magnetoresistance of the magnetic tunnel junction is greater than 160% at room temperature.

73. The structure of Claim 70, wherein at least one of the underlayer and the overlayer includes antiferromagnetic material that is exchange biased with the ferromagnetic material of said at least one layer, the antiferromagnetic material including at least one alloy selected from the group consisting of Ir-Mn and Pt-Mn, in which the 5 alloy is substantially (100) oriented and is either fcc or slightly distorted fcc.

74. The structure of Claim 70, wherein the underlayer includes antiferromagnetic material over at least one layer selected from the group consisting of Ta and TaN.

75. The structure of Claim 70, wherein the MgO tunnel barrier is in direct contact with the both the ferromagnetic material of the underlayer and the ferromagnetic material 10 of the overlayer.

76. The structure of Claim 70, wherein the MgO tunnel barrier has a thickness of between 3 and 50 angstroms.

77. The structure of Claim 65, wherein the underlayer and the overlayer include respective non-ferromagnetic, non-ferrimagnetic metals.

15 78. The structure of Claim 65, wherein one of the underlayer and the overlayer includes a layer of ferromagnetic material, and the other of the underlayer and the overlayer includes a layer of non-ferromagnetic, non-ferrimagnetic metal.

79. The structure of Claim 78, wherein:

- i) the amount of any oxide separating the MgO tunnel barrier from the underlayer and 20 the overlayer is sufficiently low, and
- ii) the MgO tunnel barrier, the underlayer, and the overlayer are sufficiently free of defects,

that the spin polarization of tunneling current passing through the structure is greater than 50%.

80. The structure of Claim 78,

i) the amount of any oxide separating the MgO tunnel barrier from the underlayer and

5 the overlayer is sufficiently low, and

ii) the MgO tunnel barrier, the underlayer, and the overlayer are sufficiently free of defects,

that the spin polarization of tunneling current passing through the structure is greater than 70%.

10 81. The method of Claim 78, wherein the ferromagnetic material is in direct contact with the MgO tunnel barrier.